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VEGETATION OF THE ROYAL BOTANIC GARDENS ANNEXE AT CRANBOURNE, VICTORIA

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ABSTRACT: The Royal Botanic Gardens Annexe at Cranbourne supports 200 ha of closed-heath, closed-scrub and low closed-forest (*sensu* Specht, 1970). Variation of the floristic composition of the vegetation is mostly continuous along topographic and edaphic gradients, but sharp discontinuities occur where permanent water is at, or close to, the soil surface.

Studies made of regeneration after clearing suggests that if the topsoil is not removed floristic regeneration is complete within 8 years, while structural regeneration may take up to 30 years.

A method for sorting two-way tables for vegetation description is included. This method employs a polythetic, agglomerative, non-hierarchical clustering procedure, with a data editing facility.

INTRODUCTION

The Royal Botanic Gardens Annexe at Cranbourne is approximately 200 ha of undulating land situated in a rural area some 50 km from Melbourne and about 15 km from both Westernport and Port Phillip Bays (Fig. 1). It was purchased by the Botanic Gardens from the Department of the Army in 1969 for the purposes of developing a native plant botanic gardens, a wildflower reserve and an area for biological research. Since the date of purchase developmental activities have been minimal and this study presents information relevant to the present ecology and future management of the Annexe, and lays the groundwork for subsequent biological research.

The first step in this program was to establish the variety, frequency and distribution of the plants contained in the Annexe. This information will become the reference data for future studies on the dynamics of vegetation and animal populations of this area (Braithwaite & Gullan 1978).

SAMPLING METHODS

Raw data for the survey were floristic and structural descriptions of vegetation collected (during 1972) at 168, 5 x 5 m quadrat sample sites. These sample sites were arranged on a regular grid, as recommended by Williams (1971), with intervals of 100 m between sites. All plants (with the exception of fungi) which projected over, or grew within the quadrat area were recorded and each was assigned a value based on a visual estimate of its cover/abundance (Gullan *et al.* 1976). Structural information was based on a simple division of the vegetation into strata, and a visual estimate of the cover for each stratum.

Quadrat sites were located with the aid of a recent (1972) 1 : 10,000 scale black-and-white aerial photograph (Pl. 16, above) with a regular, 1 cm interval grid superimposed on it.

METHODS OF ANALYSIS

The floristic data were analysed with the aid of a technique for sorting two-way tables which incorporates a polythetic, agglomerative, non-hierarchical clustering procedure for both normal and inverse analyses, and an editing procedure for removing uncharacteristic species (i.e. those not indicative of any vegetation group) from the data before the inverse analysis.

This technique, although incorporating a number of procedures previously described in the literature, is original in design and has not been used in vegetation studies before. A complete description of its mode of operation is given in Gullan (1975).

The Clustering Procedure

The clustering procedure was devised by Carlson (1972) for psychological studies. Clusters are formed so that individuals within a cluster should

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be more similar to each other than to any individual outside the cluster. In an unmodified form, however, Carlson found that the resulting classification was trivial. Clusters usually contained three individuals or less and the majority of individuals were not clustered at all. He therefore introduced a heterogeneity parameter into the algorithm so that '. . . an object was no longer required to have all the similarity indices for members of its cluster higher than its similarity indices for nonmembers. Five percent of these indices could now be exceptional'.

Bradfield (1975) employed the Carlson clustering method in an analysis of vegetation data from the coast of Lake Erie. The analysis was run several times on the same data, but each time with a different heterogeneity level (0, 5, 10, 15 and 20%). This procedure resulted in a series of classifications with successively larger clusters and when these different classifications were presented together the result resembled a conventional hierarchical dendrogram (see Bradfield's 'skyline diagram'), although each level was calculated independently of the others.

For the analysis in this paper a modification to the Carlson technique has been made which requires that a minimum similarity between any two members of a cluster be specified. This avoids the problem of an individual joining a cluster, for which it has no strong affinity, simply because it is very dissimilar to all individuals outside the cluster.

Because the Carlson technique can be executed at different levels, the relationships between clusters can be shown at least as well as with hierarchical dendrograms, and as each level is calculated separately, the calculations can be made for as many levels as required. This latter property, found partially in divisive systems but absent from hierarchical, agglomerative systems, is useful when computer facilities are limiting. This property is also useful for sorting two-way tables, particularly when choosing character species for an inverse analysis.

Similarity Coefficient

The Carlson clustering procedure operates entirely on a matrix of similarity values generated prior to the analysis. In this paper the so-called

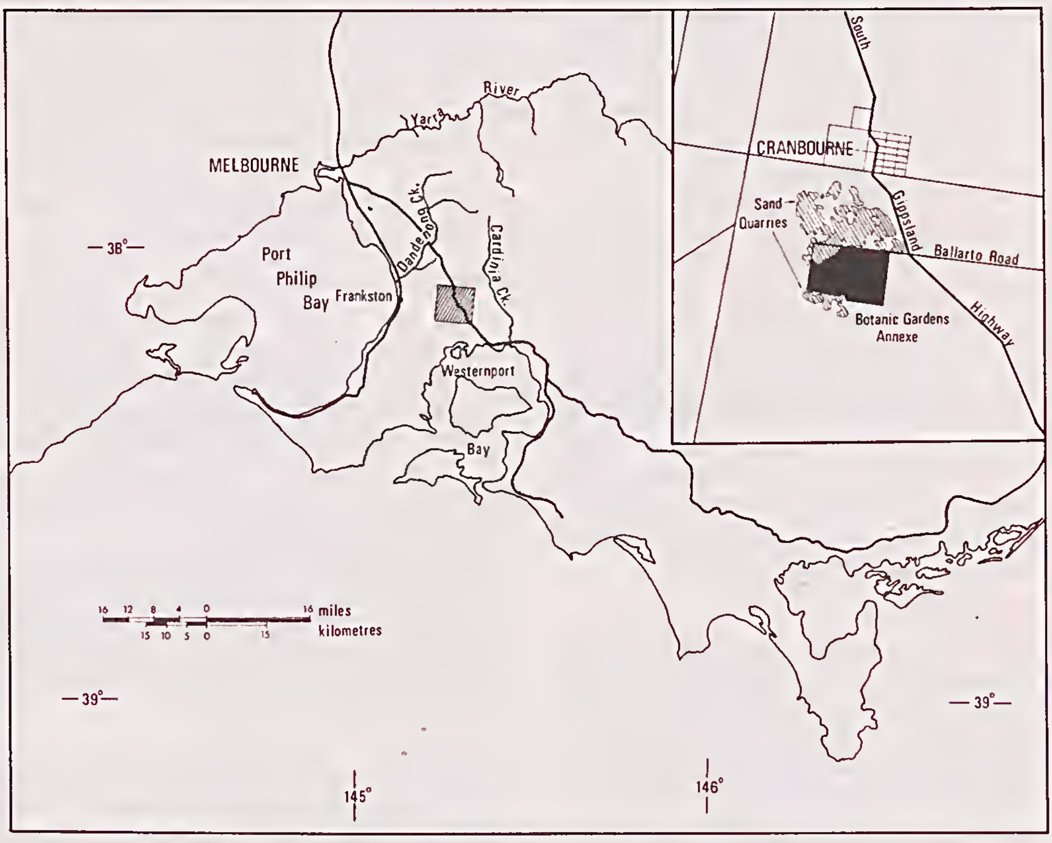

FIG. 1 — Locality map of Cranbourne Annexe. Inset is an enlargement of the hatched area on main map.

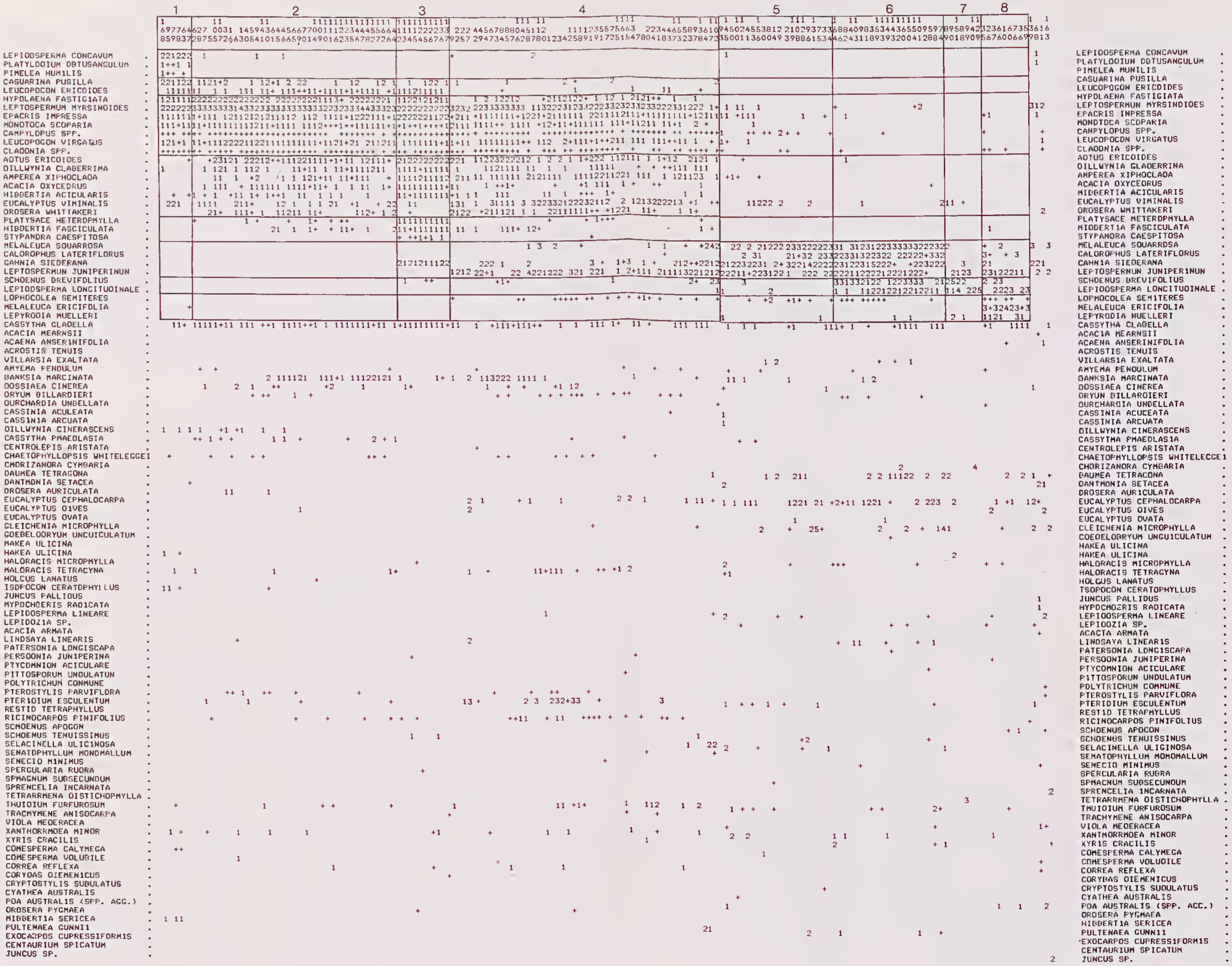

FIG. 2 — Two-way table of 168 quadrats from the Cranbourne Annexe. Vertical lines divide data into quadrat groups, horizontal lines delineate species groups.

'quasi-metric' (Williams & Dale 1965) Jaccard coefficient (Jaccard 1908) was used to create a similarity matrix.

The Jaccard is favoured in this analysis because of its ease of calculation and the straight forward concept of similarity that it conveys.

The similarity matrix takes into account only presence/absence information. Cover/abundance symbols are used simply to compare the variation of plant performance between quadrats, after the analysis is complete. This choice was made because the most useful aspect of two-way tables is their ability to give a visual impression of group composition and the interrelationships between groups. This impression is strongest when adjacent groups differ qualitatively rather than in the changing quantity of species which they share. The analysis thereby produces the most distinctive groups on a two-way table.

Inverse Analysis

In most attempts at inverse analysis a strategy identical to that used for the normal analysis has been employed. However the structure of inverse data is quite different from the normal data set, particularly with reference to species distribution. There is usually a much greater variation in the number of quadrats in which a species may occur than variation in the number of species in a quadrat. An inverse analysis is therefore often confused by the presence of species that occur only a few times, or by those that appear to be distributed randomly.

Austin and Grieg-Smith (1968) have suggested that in some, if not most cases, less than a third of the species in a data set are necessary to demonstrate the major trends in an ordination. Similarly Orloci and Mukkatu (1973) have used a similar premise to define criteria by which species can be ignored in data collection.

In the analysis described in this paper 70% of species were removed from the data set before the inverse analysis. The criterion for removal of these species is based on their frequency of occurrence in clusters of quadrats formed by the normal analysis. If a species occurs in less than N% of the quadrats of *any* cluster then it is left out of the inverse analysis. N is chosen by the analyst and provides a third means by which he may control the heterogeneity of the classification.

The components of the table sorting procedure described above have been incorporated into a single computer program (called MAGIC, Gullan 1975). The clustering part of the program is a modified version of CARLS/CLUST, a program written in FORTRAN IV by Carlson (1972).

Hand Sorting

When the Carlson clustering procedure is run using several heterogeneity levels (Bradfield 1975, Gullan 1975) the species and quadrats can be ordered extremely well and intergroup relationships are demonstrated effectively. However, this process is rather lengthy (both computationally and manually) and in the program MAGIC a single heterogeneity level only has been chosen. This means that although the most similar species and quadrats are placed together in clusters, the clusters themselves are not ordered. The sorting of these clusters must be carried out, by hand, after the analysis, when a second table is printed (using a table printing program modified from ZUMONT/PRINT, Gullan *et al.* 1976) in which the groups are rearranged and any obvious misclassifications corrected.

THE TWO-WAY TABLE AND ITS INTERPRETATION

The floristic data have been divided into *eight* groups, by the above procedure. These are described below.

Group 1: Characteristically a low open vegetation (1 m or less) with scattered, mallee-form* *Eucalyptus viminalis* (3 to 4 m), Group 1 is confined to exposed hilltops where A1 horizons of the soil are shallow (Table 3). A number of species occur in this group that grow nowhere else in the Annexe. Most of these plants are small herbs or shrubs less than 50 cm high, often with a creeping, scrambling or prostrate habit (e.g. *Platylobium obtusangulum, Goodenia geniculata, Drosera planchonii, Lepidosperma concavum*).

Group 2: Group 2 is slightly taller (1 to 2 m) and denser vegetation than Group 1 with more abundant and larger (up to 7 m) eucalypts. In this group *Leptospermum myrsinoides* is generally more abundant than in other groups although it does not grow as tall here as it does in Group 4. This group is distinguished from Group 1 floristically by a greater species richness (Fig. 2), although most of these species are physiognomically very similar (most are small-leafed, sclerophyllous shrubs).

Group 3: This group is confined to a single area of approximately 18 ha near the northern boundary of the Annexe. It is physiognomically very similar to Group 1 but floristically much more closely related

*(All vascular plant nomenclature according to Willis 1962, 1972).

TABLE 1.

DESCRIPTION OF THE STRUCTURE AND FLORISTIC COMPOSITION OF THE VEGETATION.

Species names are in the order that they appear on the two-way table.

In Groups, all species with less than 50% frequency are ignored, as are species considered characteristic of the community.

Since Groups 7 and 8 are regarded as having full community status, structural descriptions for them are included.

COMMUNITY 1.

STRUCTURAL DESCRIPTION.

Tree Layer: Sparse (+) to dense (3) canopy of *Eucalyptus viminalis*, heights ranging from 4 to 12 m.

Shrub Layer: Dense cover of sclerophyllous shrubs (up to 100% cover), predominated by *Leptospermum myrsinoides* (50 cm to 3 m high).

Ground Layer: Mat of lichens (*Cladonia* spp. and *Cladia aggregata*) and mosses (*Campylopus* spp.) interspersed with locally abundant *Drosera whittakeri* and *Pterostylis parviflora* (in late winter to early spring).

Soil Type: Podzol.

CHARACTERISTIC SPECIES OF THE COMMUNITY

Species	Frequency
Leptospermum myrsinoides	100%
Epacris impressa	98%
Hypolaena fastigiata	82%
Monotoca scoparia	93%
Leucopogon virgatus	90%
Campylopus spp.	90%
Cladonia spp.	91%

GROUP 1.

Common Species	Frequency
Lepidosperma concavum	100%
Platylobium obtusangulum	85%
Pimelea humilis	66%
Casuarina pusilla	100%
Leucopogon ericoides	95%
Eucalyptus viminalis	50%
Dillwynia cinerascens	50%

GROUP 2.

Common Species	Frequency
Casuarina pusilla	51%
Leucopogon ericoides	75%
Aotus ericoides	80%
Dillwynia glaberrima	62%
Amperea xiphoclada	61%
Acacia oxycedrus	62%
Eucalyptus viminalis	51%
Drosera whittakeri	56%
Cassytha glabella	82%
Banksia marginata	51%

GROUP 3.

Common Species	Frequency
Casuarina pusilla	50%
Aotus ericoides	100%
Dillwynia glaberrima	100%
Amperea xiphoclada	100%
Acacia oxycedrus	100%
Hibbertia acicularis	100%
Platysace heterophylla	100%
Hibbertia fasciculata	100%
Stypandra caespitosa	70%
Gahnia sieberana	100%
Cassytha glabella	100%

GROUP 4.

Common Species	Frequency
Aotus ericoides	75%
Dillwynia glaberrima	53%
Amperea xiphoclada	80%
Eucalyptus viminalis	78%
Drosera whittakeri	70%
Leptospermum juniperinum	78%
Cassytha glabella	57%

COMMUNITY 2.

STRUCTURAL DESCRIPTION.

Tree Layer: Sparse to dense canopy of *Eucalyptus cephalocarpa* from 10 to 12 m.

Shrub Layer: Dense cover of *Melaleuca squarrosa* and *Leptospermum juniperinum*, from 2 to 7 m high.

Ground Layer: Open, with occasional liverwort ground cover to dense swards of sedges 50 cm to 2 m high.

Soil Type: Humus podzol.

CHARACTERISTIC SPECIES OF THE COMMUNITY

Species	Frequency
Melaleuca squarrosa	90%
Gahnia sieberana	92%
Leptospermum juniperinum	85%

GROUP 5.

Common Species	Frequency
Eucalyptus cephalocarpa	59%

GROUP 6.

Common Species	Frequency
Calorophus lateriflorus	90%
Schoenus brevifolius	85%
Lepidosperma longitudinale	65%
Cassytha glabella	50%

GROUP 7.

STRUCTURAL DESCRIPTION

Tree Layer: Absent.

Shrub Layer: Occasional small (less than 2 m) *Leptospermum juniperinum.*

Ground Layer: Dense sward of sedges (up to 100% cover).

Soil Type: Humus podzol.

CHARACTERISTIC SPECIES OF THE GROUP

Species	Frequency
Leptospermum juniperinum	70%
Schoenus brevifolius	70%
Lepidosperma longitudinale	85%

GROUP 8.

STRUCTURAL DESCRIPTION

Tree Layer: Very infrequent occurrence of *Eucalyptus cephalocarpa* or *Eucalyptus ovata*. Generally absent.

Shrub Layer: Dense *Melaleuca ericifolia* thickets (3–8 m), interspersed with slightly smaller *Leptospermum juniperinum*.

Ground Layer: Fairly dense cover of sedges and rushes, and mats of *Lophocolea semiteres* (Liverwort) on the leaf litter and bark.

Soil Type: Humic gley.

CHARACTERISTIC SPECIES OF THE GROUP

Species	Frequency
Leptospermum juniperinum	89%
Lepidosperma longitudinale	66%
Lophocolea semiteres	77%
Melaleuca ericifolia	100%
Cassytha glabella	66%
Lepyrodia muelleri	66%

to Group 2. The land on which this group is found was cleared of vegetation in 1968 and prior to this time probably supported Group 2 vegetation. This was deduced from examination of pre-1968 (Pl. 16, below) aerial photographs and the fact that almost the entire area is at present surrounded by Group 2 vegetation. Regeneration is not yet complete but it is advanced enough to demonstrate the similarities between this area and Group 2. Notable differences from Group 2 are the absence of *Eucalyptus viminalis* (seedling establishment is apparently very slow) and *Drosera whittakeri* (this plant appears to favour moist, shaded areas which are rare in Group 3 due to the openness of the young vegetation), the increased abundance of *Hibbertia acicularis, H. fasciculata* and *Epacris impressa* (always indicators of areas recently disturbed in the Annexe), and the presence of *Stypandra caespitosa* (found nowhere else in the Annexe) and *Gahnia sieberana*.

The entire 18 ha area is floristically and physiognomically very uniform, and apart from the differences mentioned above, appears to be developing as Group 2 vegetation.

GROUP 4: This vegetation is found primarily on the lower slopes of the Annexe where the A1 horizons of the soils are deep and organic (Table 3). When it is matûre, Group 4 vegetation supports *Eucalyptus viminalis* and/or *E. cephalocarpa* which are larger (up to 15 m) and more abundant in this group than in Groups 1 to 3. However this is not evident from the floristic information in the two-way table as most of the eucalypts in Group 4 are immature due to clearing activities in the 1960's (Pl. 17, above).

GROUP 5: This vegetation is found primarily in depressions between hills and abuts Group 4 vegetation. As in Group 4 the canopy of *Eucalyptus viminalis* and *E. cephalocarpa* is often absent from this group due to the immaturity of the vegetation, but in areas where clearing has not taken place one of these eucalypts (usually *E. cephalocarpa* in Group 5 and *E. viminalis* in Group 4) will form a fairly dense canopy.

The understory of Group 5 is floristically much poorer than that of Groups 2 and 4. Only three species, *Melaleuca squarrosa, Leptospermum juniperinum* and *Gahnia sieberana* are consistent components of Group 5 understory. Thickets formed by the two myrtaceous shrubs often have little more than a thick mat of leaf litter covering the ground beneath them.

GROUP 6: This vegetation grows in wetter depressions than Group 5 and differs from that group in having a more open eucalypt canopy (again this is referring to mature vegetation as this cannot be gathered from the floristic information contained in Fig. 2) and a greater diversity of understory plants, including three monocotyledon species.

GROUP 7: Group 7 is a poorly defined collection of quadrats which have in common a low species richness and a dominance of one or two species of sedge (*Lepidosperma longitudinale, Cladium tetragonum, Chorizandra cymbaria, Schoenus brevifolius*). All quadrats occur in waterlogged soils (usually 10 — 30 cm of standing water most of the year) and completely lack a tree canopy.

GROUP 8: Group 8 quadrats are found in wet, humic gley soils (Table 2) and are characterised by the presence of *Melaleuca ericifolia* and *Lepyrodia muelleri* (Restionaceae). This vegetation is physiognomically very similar to Group 6 where *M. squarrosa* replaces *M. ericifolia* and *Calorophus lateriflorus* (Restionaceae) replaces *L. muelleri.*

Although the two-way table has been divided into eight groups the most striking feature of the table is its division into two major clusters of species and quadrats. This division is the most important one from the points of view of floristics, physiognomy and environmental variables and represents the two main vegetation communities of the Annexe.

COMMUNITY 1.

Community 1 is made up of Groups 1— 4. Seven species occur commonly (more than 80% presence in every group throughout the community, Table 1), five of which are vascular plants (*Cladonia* is a lichen and *Campylopus* is a moss). Of these five species only *Hypolaena fastigiata* is a monocotyledon, and the rest are small-leafed, sclerophyllous, dicotyledon shrubs. *Leptospermum myrsinoides* is the most prominent of the dicotyledons and forms a significant proportion of the plant biomass in the Annexe. Winkworth (1955) and Jones (1968) calculated that *L. myrsinoides* made up more than 50% of the plant biomass in an area of heath at Frankston, Victoria, which is floristically very similar to that of the Cranbourne Annexe. It varies in size from a small, almost procumbent shrub less than 50 cm high in Group 1, to a fairly large bush (2 to 3 m) forming dense thickets in Group 4. In nearly every quadrat in which it is found *L. myrsinoides* is the most abundant plant (Fig. 2) usually with a cover/abundance value of 2 or 3.

There are noticeable floristic differences between Groups 2 and 4. *Casuarina pusilla* and *Leucopogon ericoides*, common in Groups 1 to 3, are infrequent in Group 4, and *Hibbertia fasciculata, H. acicularis, Acacia oxycedrus* and *Platysace heterophylla* become much less abundant (Table 1). *Gahnia sieberana* and *Leptospermum juniperinum*, found also in Groups 5, 6 and many Group 4 quadrats are almost entirely absent from Group 2.

Before clearing operations began in 1966 the transitions between Groups 1, 2 and 4 were physiognomically (and probably floristically) indistinct (Pl. 17, below). These groups are arbitrary cut-off points on what was a continuum. In 1976 however, much of the Group 4 vegetation was physiognomically similar to that of Group 2 because parts of both were immature and supported young eucalypts. It is to be expected that the continued growth and proliferation of eucalypts in Group 4 will result, not only in a physiognomic transition, but also a change in floristics. In mature stands of Group 4 vegetation surviving in the Annexe at present (e.g. quadrat 153, Fig. 2) some small sclerophyllous shrubs, common in Group 2, are completely absent (those plants described earlier as distinguishing the two groups), whereas they are occasionally found in areas where Group 4 vegetation is immature and the eucalypt canopy is sparse.

COMMUNITY 2.

The second community, made up of Groups 5 and 6, is characterised by three species, *Melaleuca squarrosa, Leptospermum juniperinum* and *Gahnia sieberana*, which occur in over 90% of the quadrats of these two groups. The first two of these species form the main structural components of this community and grow in dense thickets up to 7 m high.

Like Groups 4 and 2, Groups 5 and 6 are not sharply distinct floristically or physiognomically and have been defined by an artificial division on a continuum. The transition from Group 1 to Group 6 is one of continuous variation with the exception of the sharp discontinuity between Groups 4 and 5, and four species, *Leptospermum juniperinum, Gahnia sieberana, Eucalyptus viminalis* and *E. cephalocarpa*, occur occasionally in both groups. The distribution of vegetation groups (Fig. 3) closely follows changes in topography of the Annexe (Fig. 4).

SOILS AND VEGETATION

'Cranbourne Sand' (Holmes *et al.* 1940) forms the undulating topography of the Annexe and distinguishes it from the flatter surrounding land. Much of the surrounding landscape is developed over mudstones and sandstones (Fig. 5) which have formed a fairly heavy humic gley (Stace *et al.* 1972) similar to that described by Holmes *et al.* (1940) as 'Narre Clay Loam'.

The two main soil types of the Annexe are podzols and humus podzols. The podzols are confined primarily to the tops and sides of hills, and the humus podzols are found in the depressions

TABLE 2.

DESCRIPTIONS OF MAJOR SOIL TYPES

Cranbourne Sand: Podzol.

A0	1–3 cm	Fairly dry undecomposed leaf litter. Often crust of lichens and moss.
A1	5–40 cm	Grey to dark grey sandy loam. Fairly high organic content.
A2	40–70 cm	Grey to very light grey sand. Very low in organic matter.
B1	70–75 cm	Thin, dark brown to black, sand cemented together to form hard-pan but it is easily crumbled by hand.
B2	75 cm+	Yellow to orange sand. No organic material except where long roots form pipes through it. Sometimes very deep (8 m or more).

Humus Podzol

A0	1– 5 cm	Moist undecomposed leaf litter (mainly *Leptospermum juniperinum* and *Melaleuca squarrosa*).
A1	5–70 cm	Dark brown very organic loam (almost a peat) with fairly coarse (0.5 mm) sand grains in it. Often water logged almost to the surface. Forms a liquid mud.
A2	70–130 cm	Light grey, sometimes mottled with orange. No investigation to any greater depth because of water table.

Narre Clay Loam: Humic Gley

A0	0– 4 cm	Fairly dense undecomposed leaf litter.
A1	4–25 cm	Dark grey clay-loam with some orange mottling. Friable.
A2	25–65 cm	Light grey clay with orange mottling. Usually wet and slightly sticky.
B1	65–77 cm	Dense grey clay. Very sticky and wet.
B2	77 cm+	Dense red-orange and grey mottled clay. Sometimes fairly large sand grains but always heavy, sticky and waterlogged.

(Table 2). Both soil types are described in the literature as supporting 'heath' (Specht & Rayson 1957, Coaldrake 1961, Groves 1964, Jones 1968) or 'wet heath' (Paton & Hosking 1970). Characteristically both soil types are low in pH, Ca, Mg, K, N and P.

Generally Community 1 vegetation is found on podzols and Community 2 vegetation occurs on humus podzols. The sharp transition from Community 1 to Community 2 occurs across equally abrupt changes from podzol to humus podzol. However, in those areas where Group 4 abuts Group 5 distinctions between the soil types can become difficult.

The humus podzols are usually moist and often waterlogged. The water table is seldom below the top of the A2 horizon and in winter it may rise to the Ao in Group 6, or as high as 50 cm above the soil surface in Group 7. The level of the water table may be related to the presence of a highly impermeable B1 horizon. However no hard 'coffee rock' was encountered beneath humus podzols within the Annexe (although the B horizon was not often reached due to the difficulty of excavation under water), and evidence from mining activities in and around the Annexe suggests that perched water tables are not common. The occurrence of a heavy clay, which underlies the B2 horizons, is probably the most important barrier to downward water movement.

The water table level is likely to be the most significant factor determining vegetation composition. The sharp transition between Communities 1 and 2 is almost certainly related to waterlogging of the A1 horizon of the humus podzols. Gullan (1975) demonstrated that Community 2 and Group 7 plants possess specializations for the transport of atmospheric oxygen to their roots.

Floristic differences between Groups 5, 6 and 7 (the groups found on the humus podzols) correspond to differences in water table level (Table 3a), whereas other soil physical properties (permeability and particle size distribution) are relatively uniform in the humus podzols. However Groups 1, 2 and 4 (the undisturbed groups on podzols) are all found on well aerated soils not subjected to waterlogging, and floristic differences between them are perhaps more closely related to the thickness and permeability of the A1 horizon (Table 3b). The A1 horizon holds almost all of the dead organic material (Findlay 1976) and most of the living plant roots (Jones 1968). In areas where this horizon is thin and fairly dry (Group 1) the plant biomass is low and the vegetation stunted (e.g. *Eucalyptus viminalis* has a mallee habit in Group 1).

TABLE 3.

(a) Depth of water tables for vegetation groups found on humus podzols. Figures are distances above (+) or below (−) the soil surface.

	Min (cm)	*Max (cm)*
Group 5	*−25*	*−80*
Group 6	*− 2*	*−30*
Group 7	*+50*	*− 5*

(b) Range of A1 horizon thickness and permeabilities for podzol groups. Permeability measured using a falling head permeater (Means & Parcher 1964). Measurements taken on soil from the centre of each horizon.

	A1 Thickness (cm)	*Perm. cm sec.$^{-1}$*
Group 1	20 − 25	5 x 10^{-4}
Group 2	30 − 40	1 x 10^{-4}
Group 3	40 − 65	5 x 10^{-5}

Within Community 1 there is a close relationship between topography and the A1 horizon which is thicker and less permeable at lower elevations. Consequently the variation in availability of nutrients and water in the A1 is compounded by the effects of exposure related to topographic variation.

These observations agree with observations on the relationships between soils and vegetation in Europe. Gimingham (1972) emphasizes the importance of drainage in heathland podzols to the development of root systems, and Hansen (1976) demonstrates a close relationship between pH, thickness and field capacity of the 'mor layer' (A1 horizon) and vegetation composition in Danish heaths.

In a few small and isolated areas in the Annexe, a humic gley soil is found which supports Group 8 vegetation. This soil is waterlogged to the surface in winter and is always wet past a depth of about 25 cm.

Plants on the humus podzols are adapted to a wet soil environment and vegetation variation may relate to the effectiveness of plant species in overcoming periodic soil anaerobiosis, and their ability to reproduce under waterlogged conditions. For example, Group 7 plants are mostly rhizomic and reproduce largely vegetatively. Reproduction by seed has obvious limitations in an environment that is almost constantly covered by water. The occasional *Leptospermum juniperinum* in Group 7 may be the result of brief drying out periods where rapidly germinating plants can become established. *L. juniperinum* seeds will often germinate in 36 hours and grow rapidly in the first few weeks (Gullan 1975).

Plants of the humic gley also have special mechanisms for survival on waterlogged soils, but the different floristic composition of Group 8 may relate to the efficiency of plant root penetration of clay or to a better utilization of the generally higher N and P composition of gley soils (Stace *et. al.* 1972).

REGENERATION

The aerial photographic history of the Cranbourne Annexe (Pl. 16, 17) shows clearly that since 1939, large parts of the area have been subjected to clearing (Fig. 6). From 1964 to 1966 vegetation over an area of about 90 ha was cut down, and in 1968 a smaller area (about 18 ha) was cleared. Most of the latter had been cleared four years before. The 1964-66 clearing was a cutting operation and reduced the vegetation to about 10 — 20 cm in height (this height was determined from stereo triplets of aerial photographs using a Zeiss stereomicrometer). Most of the trees in this 90 ha were removed from the Annexe, as few fallen trunks are visible today or can be seen in 1966-68 photographs. An area (about 4 ha) at grid point D 10 (Fig. 3) shows signs of excavation of soil and plants. It is possible that the cropped vegetation was piled here before removal or burning.

The 18 ha area was more drastically disturbed than the larger area. The clearing here resulted in the removal of the top few centimetres of soil as well as the vegetation (Pl. 16, below). The soil and vegetation was pushed into rows to partition the area.

These cleared areas provide an opportunity to monitor regeneration patterns in the Cranbourne vegetation, and to measure growth rates of plants after disturbances.

That much of the vegetation in Groups 4, 5 and 6 was immature was indicated by the evidence that eucalypts in those groups were small, and *M. squarrosa* and *L. juniperinum* in Groups 5 and 6, were often shorter than in other areas. All the quadrats that have been designated immature are found in the hatched area on Fig. 6 cleared between 1964 and 1966. Therefore the eucalypts in these groups were less than 8 years old at the time of the survey, although this is not necessarily true of the other vegetation.

Clearing of the 90 ha area involved only a reduction of the vegetation. Smaller plants, plus the stumps of larger shrubs, probably remained intact (Pl. 17, above). Specht & Rayson (1957) pointed out that a large majority of heath plants regenerate rapidly after fires, even if the entire above ground portion of the plant is destroyed. The same is true of plants after clearing: if part of the plant above ground is still alive, the regeneration need not begin at the roots. Thus in many cases, particularly in Group 4, the vegetation other than the eucalypts appears quite mature and probably has the same floristic composition as that which it had before clearing. The eucalypts, however, must regenerate from upturned stumps (the trees were pushed down rather than cut, as overturned trunks are present but no cut stumps) or seed, thus their regrowth is slower.

Several areas of Group 2 vegetation were cleared during the 1964-66 period. However Group 2 vegetation is both floristically and physiognomically very uniform. This means that after eight years the vegetation of Group 2 has grown from about 20 cm high to a height indistinguishable from vegetation that is at least 33 years old. It appears that the first few years after clearing produce rapid regrowth of scrub vegetation and then the growth rate slows down considerably.

For Group 4 eight years is obviously insufficient time for regrowth to restore the vegetation to its original state. Aerial photographs show that in most places where quadrats belonging to Group 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
K								2	4	6	6	4	2	6	6	4	2
J							2	2	2	6	6	7	2	4	6	4	5
I						4	2	3	3	3	6	7	2	4	6	6	5
H						2	2	3	3	3	3	5	7	2	5	6	6
G						2	2	3	3	3	3	2	5	4	5	4	5
F	5	2	1	5	4	6	7	5	6	5	6	2	2	4	2	5	2
E	8	2	1	1	5	6	6	4	4	4	6	4	7	6	7	6	6
E/D			1														
D	8	8	2	2	1	4	2	8	4		2	2	2	4	4	6	5
D/C								4									
C	4	4	2	2	2	1	4	4	5	4	4	5	4	2	2	4	6
B	4	8	4	2	5	5	4	2	5	5	8	8	8	6	4	2	5
A	8	8	4	4	5	2		4	2	4	4	4	4	4	4	5	4
										4	4	4	4	2	2	4	4

FIG. 3 — The distribution of Groups 1–8 in the Cranbourne Annexe. Points represent quadrat sites 100m apart.

Correspondence of grid references to quadrat numbers on the two-way table:

Grid Ref.		Quadrat No.	Grid Ref.		Quadrat No.
Z10 – 17	=	1– 8	G6 – G17	=	110–121
A1 – A17*	=	9– 24	H6 – H17	=	122–133
B1 – B17	=	25– 41	I6 – I17	=	134–145
C1 – C17	=	42– 58	J7 – J17	=	146–156
D1 – D17	=	59– 75	K8 – K17	=	157–166
E1 – E17	=	76– 92	D/C8	=	167
F1 – F17	=	93–109	E/D3	=	168

* Excluding A7

FIG. 4 — Topographic sketch map of the Cranbourne Annexe. Intervals between fine lines are 5 feet (1.5 m).

are found, the vegetation had a complete eucalypt canopy before 1964 (Pl. 17, below). Therefore today Group 4 is physiognomically variable although it is floristically uniform. This variability is artificially induced and is presumably not permanent.

Most quadrat sites in Groups 5 and 6 had fairly continuous eucalypt canopies prior to 1964 and regeneration has not been complete. In all probability Groups 5 and 6 were originally physiognomically similar and differed primarily in the floristics of their ground layer plants. These floristic differences may have been due to the close proximity of the water table to the surface of the soil, as both *Schoenus brevifolius* and *Lepidosperma longitudinale* (the two plants that distinguish Group 5 from 6) are common in swamps where the water table is above the surface. Or they may be due to the slightly less dense eucalypt canopy in Group 6.

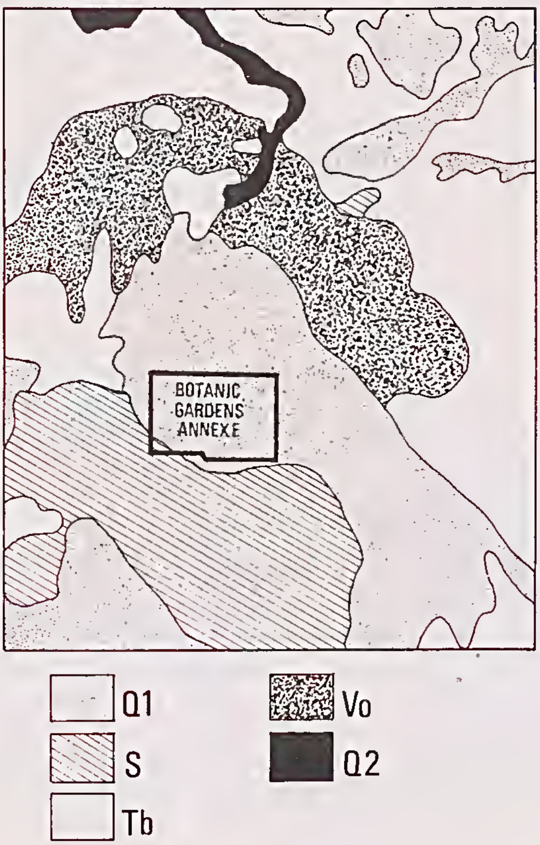

FIG. 5 — Simplified geological map of the Cranbourne Annexe and its surrounds. Vo, Older volcanic (basalt and pyroclastics); Q2, Fluviatile and lacustrine sand, silt, gravel; Tb, Ferruginous sandstone; Q1, Raised beach deposits, beach sands; S, Mudstone, Claystone, Sandstone. (Reproduced from Geological Survey of Victoria, 1:250,000 series, Queenscliff, Sheet No. SJ55—9).

Group 3 vegetation is represented as cross-hatching in Fig. 6 (i.e. cleared in 1964-66 and 1968-69). Removal of some of the upper soil layer (a few cm) makes it different from the other period of clearing documented above. It is probable that the changes incurred by this kind of clearing allowed the germination of *Stypandra caespitosa* and *Gahnia sieberana*, which are plants otherwise foreign to Community 1 vegetation. Nevertheless invasion by some introduced plants such as *Rubus fruticosus*, *Holcus lanatus* and *Hypochoeris radicata*, common outside the study area, was not evident. This may be due to the low nutrient status of the soil (particularly of phosphate) which tends to give heath plants a competitive advantage over most foreign plants (Specht 1963).

In the area surrounding quadrat site D 10 (Fig. 3) most of the sandy horizons have been removed and the introduced plants mentioned above are common, along with several others (see quadrat 68 on two-way table). The total plant cover is also low and has been for many years (see Pl. 16, and 17 above).

Regeneration of vegetation at Cranbourne is dependant upon the type and extent of the original disturbance. When disturbance is restricted to cutting back the vegetation and removing the larger trees, the floristic composition does not appear to change significantly. The vegetation will grow back to its original state with few (if any) alterations. If the vegetation consists of low shrubs without a large tree canopy (such as Groups 1 and 2), regeneration will take only a few years (apparently less than eight), but if it is a woodland, in which the trees are uprooted, (Groups 4, 5 and 6) total regeneration takes much longer (perhaps 30 or 40 years).

When clearing includes removal of the top few cm of soil, regeneration still occurs fairly rapidly (about 1 m in height in the first 4 years) but the relative proportions of its constituent species change slightly (Fig. 2). Floristic changes also

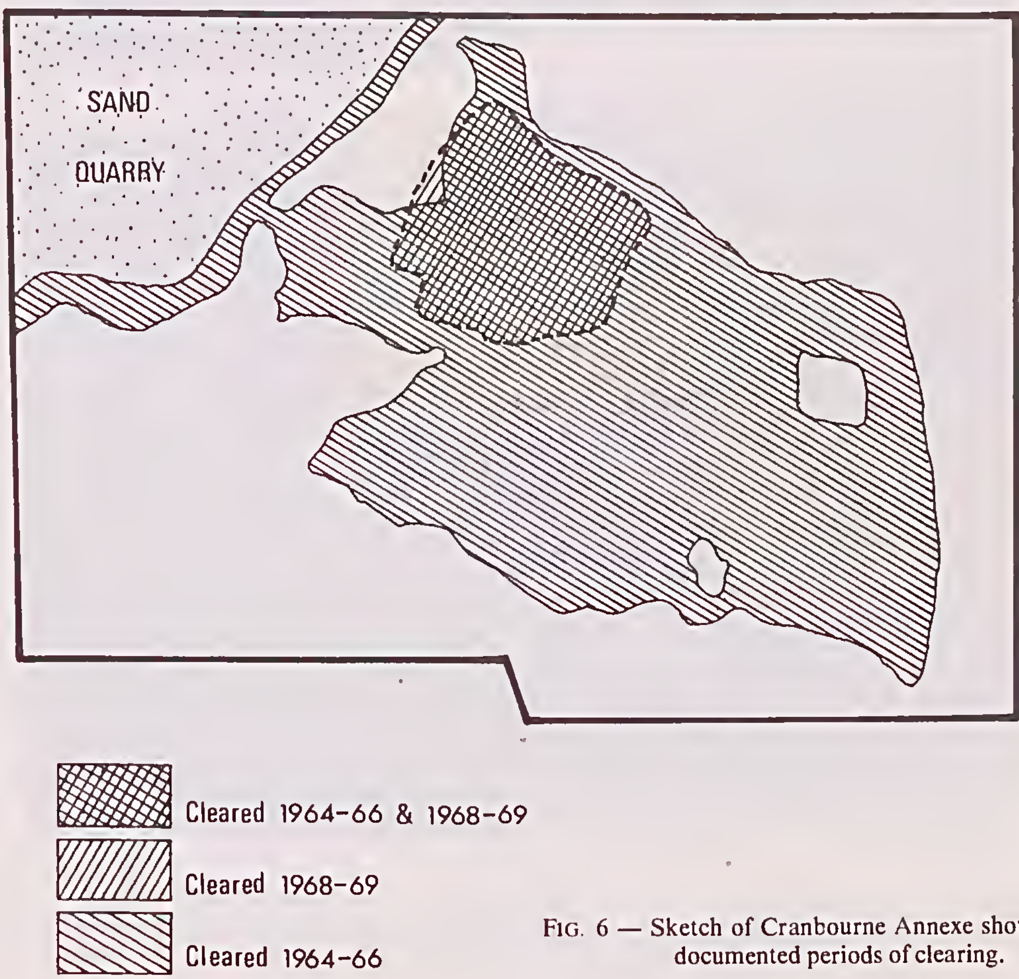

FIG. 6 — Sketch of Cranbourne Annexe showing major documented periods of clearing.

PLATE 16.

(*Above*) 1972 aerial photograph of Annexe. (*Below*) 1968 aerial photograph of Annexe. *Both photographs by courtesy of the Department of Crown Lands and Survey, Melbourne.*

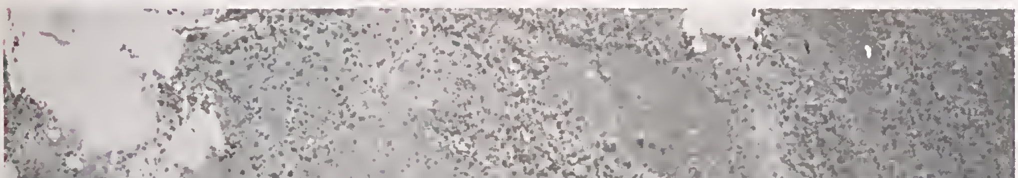

PLATE 17.

(*Above*) 1964 aerial photograph of Annexe. *By courtesy of Crown Lands and Survey, Melbourne.* (*Below*) 1939 aerial photograph of Annexe. *By courtesy of Department of National Mapping, Melbourne.*

occur, e.g. *Drosera* spp. are lost and *Gahnia sieberana* becomes common and conspicuous. However in general the vegetation appears to be the same as before clearing and reçognizable after only four years.

Where the soil is excavated to depths that result in roots and seeds being removed from the ground, the original vegetation recovers very slowly. Invasion by foreign, opportunistic plants occurs and the appearance of disturbance is maintained for some time (in the case of D 10 at least eight and perhaps twenty years, and the area still does not appear to be recovering well).

DISCUSSION

The Annexe is in an unstable state at present because of its incomplete regeneration following the three documented periods of disturbance. Information of the kind presented in this paper suggests that the structural and floristic composition of the original vegetation, and the disturbed vegetation, will in 20 years time be almost the same.

The vegetation *communities* (the vegetation units which contain the groups) are considered to have regional significance for 3 reasons. First, they differ significantly in both structural and floristic categories and are found in very different environments. Second, they can be easily distinguished from each other both on the ground and from the air. Finally, the combination of species which characterize the communities (Table 1) has been reported several times on the Mornington Peninsula and Westernport Bay areas (McLennan & Ducker 1954, Winkworth 1955, Groves 1964, Jones 1968, Grant 1974).

For these reasons it is suggested that in most cases the vegetation *communities* defined in this paper are suitable units for mapping purposes whereas the vegetation *groups* are not. The groups may be the result of disturbance factors (Group 3), be difficult to distinguish without detailed floristic

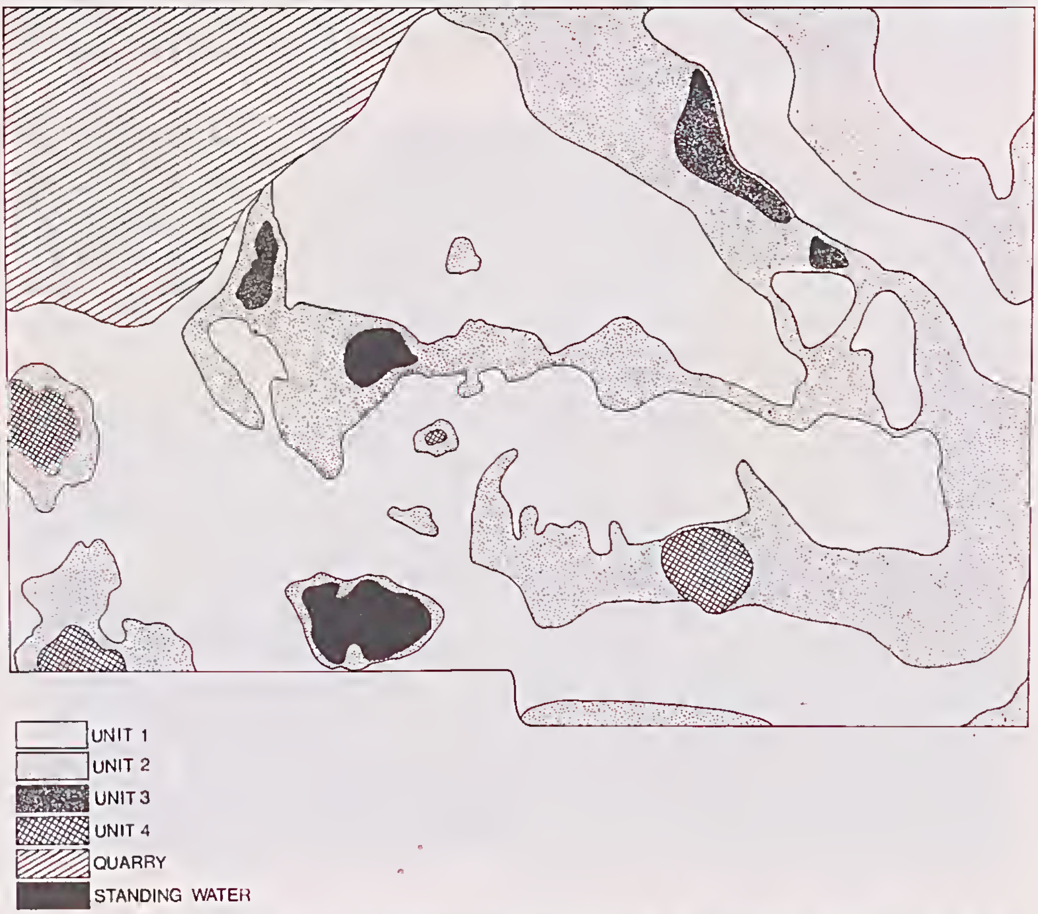

FIG. 7 — Map of the major vegetation communities of the Annexe. Units 1 to 4 are synonymous with those vegetation types described in detail in Table 1. Unit 1 = Community 1 (on Table 1); Unit 2 = Community 2; Unit 3 = Group 7; Unit 4 = Group 8.